

The Operation of TCP over Aeronautical Networks

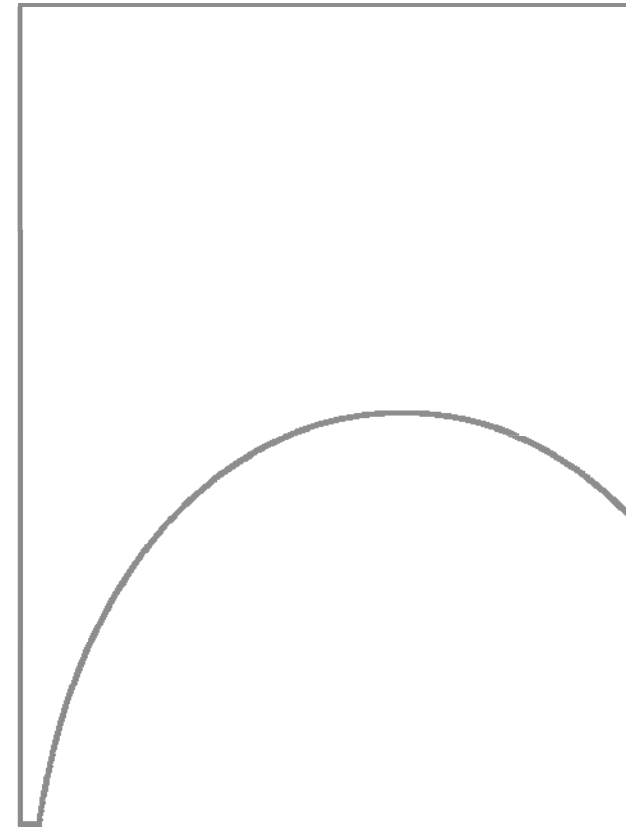
by Max Ehammer

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Outline

- Background
- How to use TCP
- Simulation details
- Simulation results
- Conclusion

Background

Current Situation

- Different Aeronautical Communication Systems
 - e.g. terrestrial, satellite communication
- Communication is based on ISO/OSI protocols & proprietary protocols
- Why didn't they use TCP/IP?
 - Historical: ATN development started when Governments required OSI.
 - Technical: IP Address Space too small for mobile routing with no single point of failure.
 - Technical: Congestion Management poor to non-existent.
 - Technical: Mobile IP inefficient and with single point of failure.

Background

Current R&D Focus

- Design of an integrated aeronautical communication network (i.e. combined usage of individual communication systems).
- Focus on air-ground communications (i.e. terrestrial and satellite)
- Everything should be based on IPv6.



Background

Goals

- **Ubiquitous and secure** communication.
- Usage of “commercial of the shelf” (COTS) products.
- Usage of mature protocols.
- Cost reduction.

- Looking at one of such candidate (COTS) protocols ...

Transmission Control Protocol (TCP)

How To Use TCP

ATM Traffic Characteristics

- Most Application Layer messages are short!
- **Majority of messages** has a size of approximately **20 bytes** to a **few hundred bytes**.
- **There are a few “large”** messages in the order of **several kilobytes**.
- Message **inter-arrival** times in the range of **seconds** to **minutes**.
- Messages are sent/generated based on events.
- Inelastic traffic.

How To Use TCP

ATS Service Class Characterization

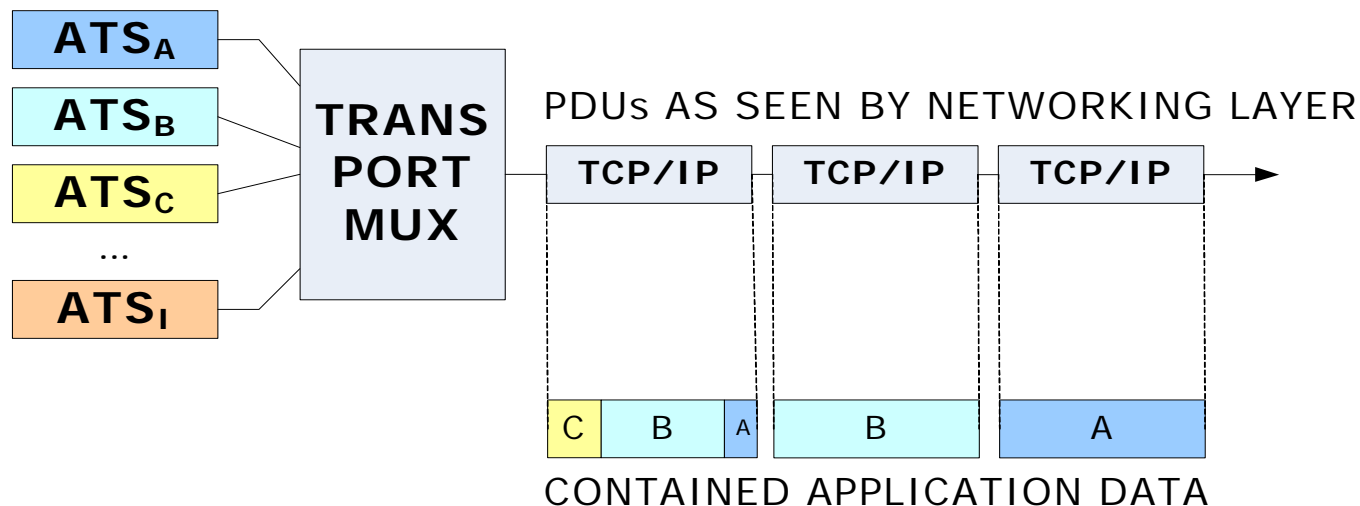
- ATS Service classes are categorized into different QoS
- From most to least demanding requirements.

Latency	95 % - R (ms)	
All	-	-
DG-A	-	-
DG-C	1400	1400
DG-D	2400	2400
DG-F	4700	4700
DG-G	9200	9200
DG-J	13600	13600
DG-K	26500	26500
DG-L	51700	51700

How To Use TCP

Multiplexing of data source

- Several data **sources** could be **multiplexed**
- **QoS/CoS handling** at networking layer then does not work
- Consequence:
 - All **networking layer QoS efforts** are performed **per transport connection**



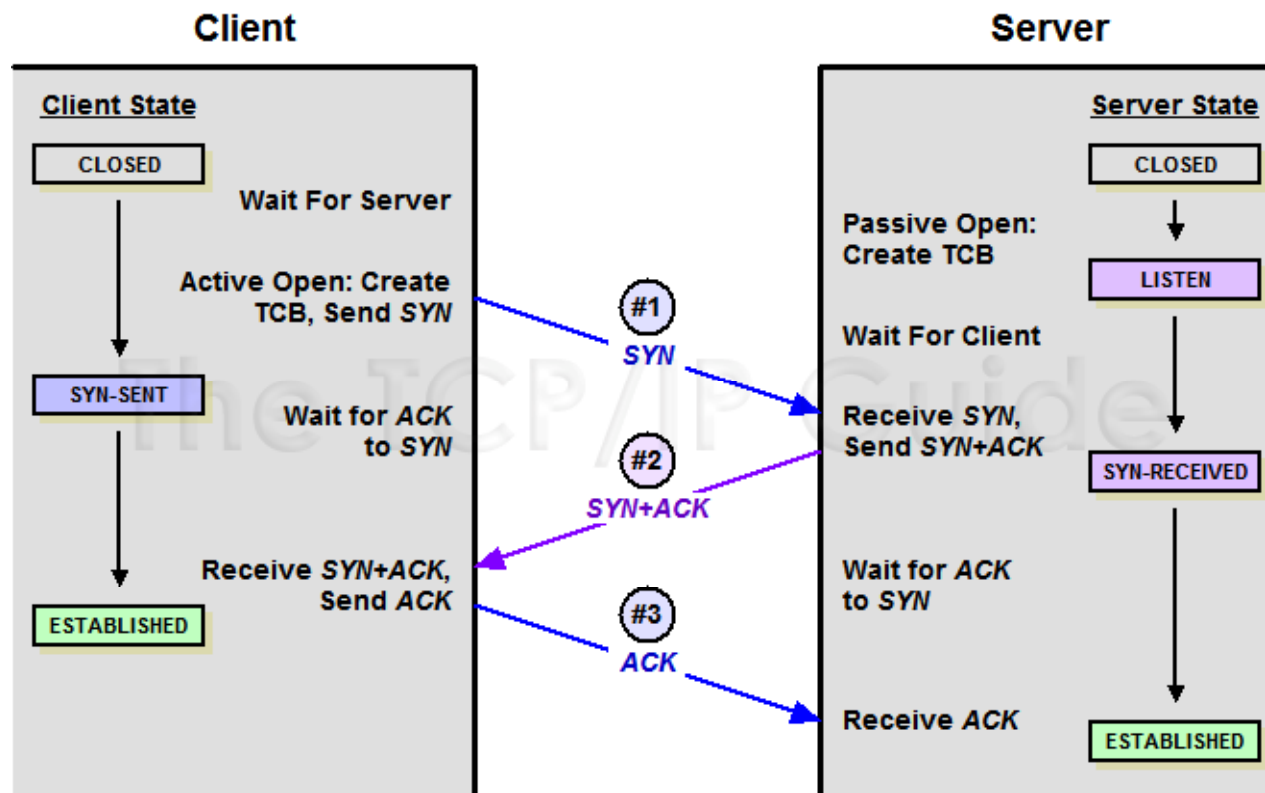
How To Use TCP

Options

- Option A: TL connections can be re-established per application.
- Option B: TL connection can be established once and kept open until handover/logoff per application.
- Option C: TL connections can be re-established per service class.
- Option D: TL connections can be established once and kept open for multiplexed services until handover/logoff.

How To Use TCP

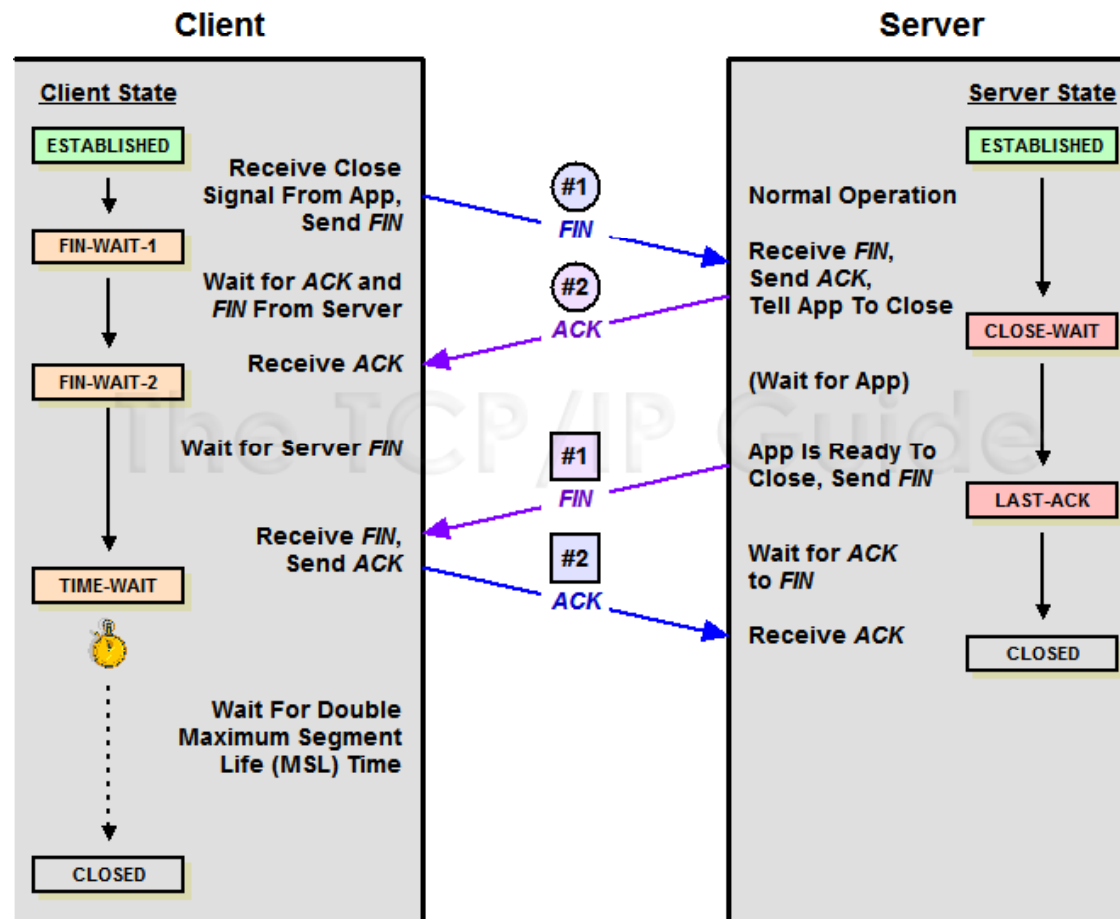
The 3-way handshake



Graphic source: <http://www.tcpiuide.com/free/diagrams/tcpopen3way.png>

How To Use TCP

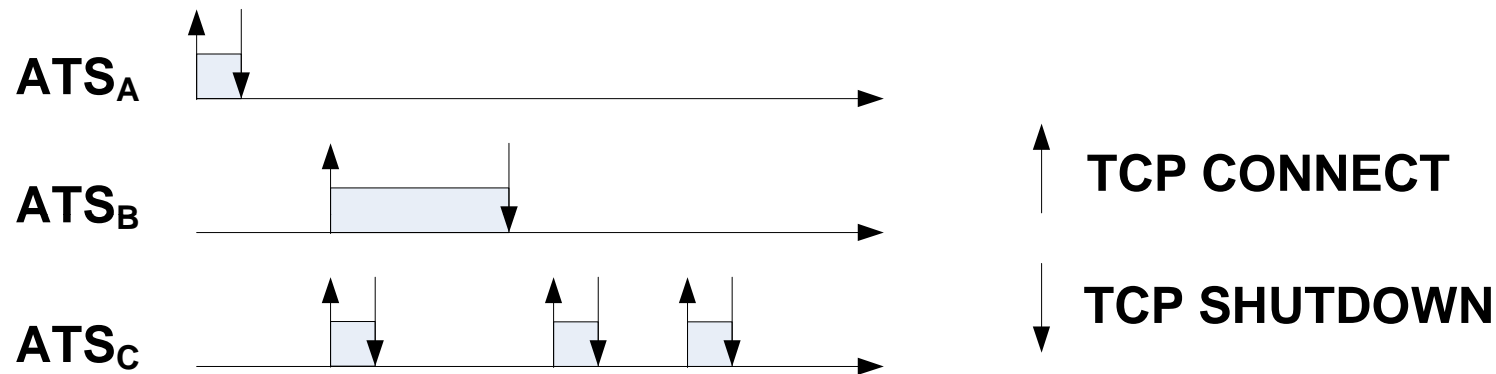
TCP connection termination



Graphic source: <http://www.tcpiipguide.com/free/diagrams/tcpclose.png>

How To Use TCP

Option A: TL connections can be re-established per application.



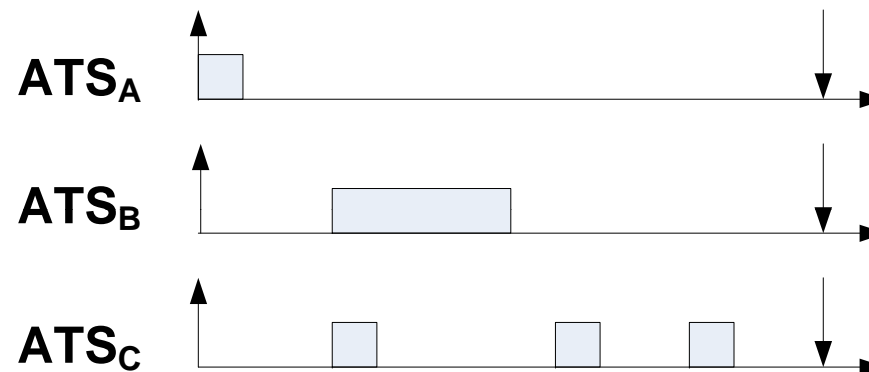
+ No CoS management problems (1 CoS per TL connection possible)

- High signaling overhead

- High connection establishment delay

How To Use TCP

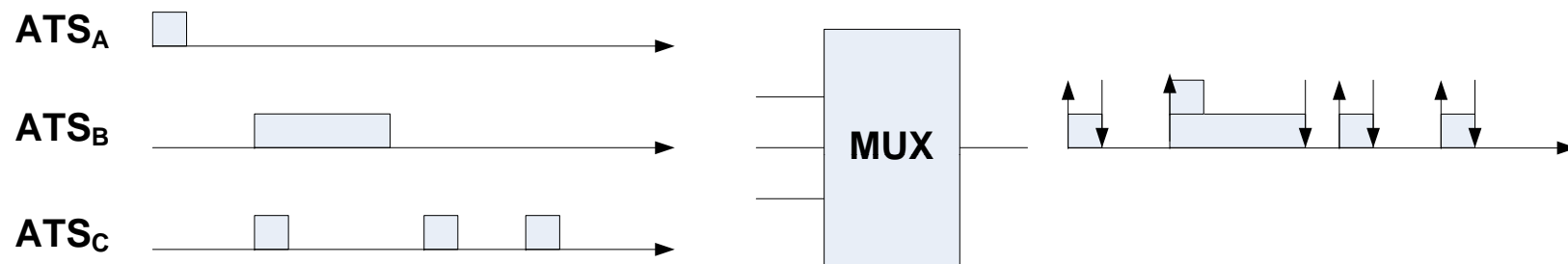
Option B: TL connection can be established once and kept open until handover/logoff.



- + No CoS problems (if proper bandwidth is available).
- + Less signaling overhead than option A.
- Large number of parallel opened connections (could be problematic).

How To Use TCP

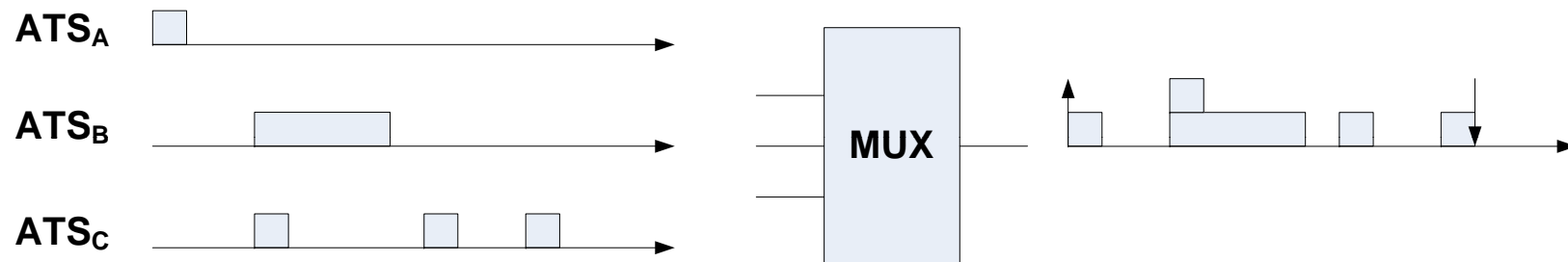
Option C: TL connections can be established per service class.



- + Some connections could be saved.
- CoS management could be problematic.
- Comparably large connection establishment delays.
- Comparably high signaling overhead.

How To Use TCP

Option D: TL connections can be established and kept open for multiplexed services until handover/logoff.



- + Smaller number of parallel open connections.
- + Smaller connection establishment delay.
- + Smaller signaling overhead.
- CoS management problems exist.

Simulation Setup

Some parameters

- **“TCP is a communication protocol, not a piece of software”**
 - This means: Different variants are available
 - Performance is dependent on implementation

- For this investigation we have implemented:
 - RFC 793
 - RFC 2001

- Mobile Operational Concept
 - 100 A/C – one hour simulation time.

Simulation Setup

Some parameters

- Relevant parts have been implemented in detail
- Data Link has been approximated
 - Medium access delay
 - Bit error rate
- Available bandwidth has been set high in order to see the effects of the different scenarios
- We have compared **Option C** and **Option D** (where a connection is closed only after a certain time of inactivity)

Simulation Results

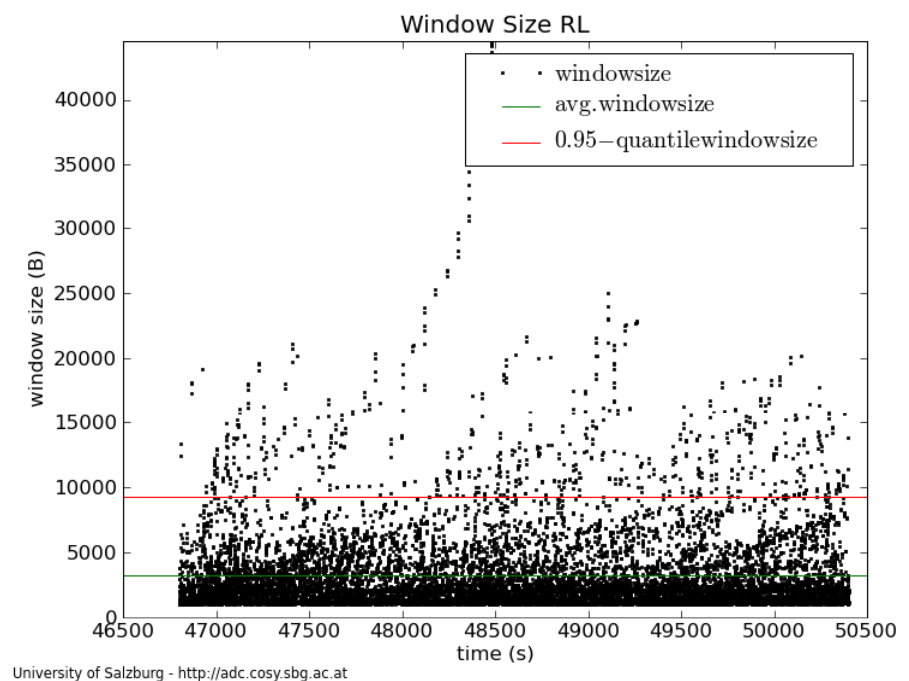
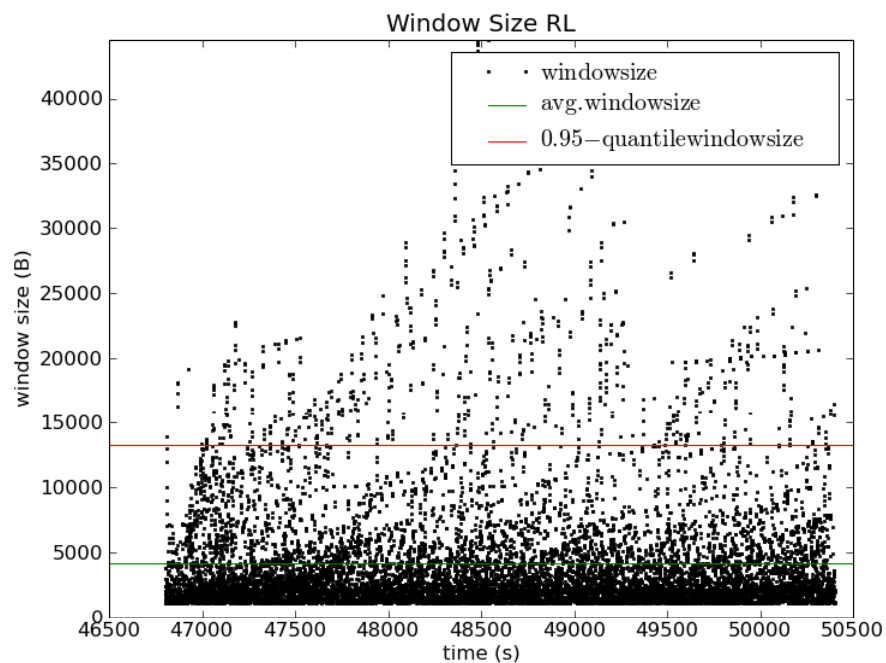
Increased Window Size

Option C

connections are hold

Option D

connections are opened and closed
on an “as needed” basis



Simulation Results

Application Layer end-to-end delay differs significantly

Latency	95 % - R		avg. (ms)		95 % - P		99 % - P	
All	-	-	2347	1604	6602	2884	11457	4600
DG-A	-	-	1513	1589	2548	2539	3734	3659
DG-C	1400	1400	1476	1525	2420	2591	3532	3517
DG-D	2400	2400	1860	1866	3111	3549	6646	6495
DG-F	4700	4700	2452	1775	3645	3065	18939	3293
DG-G	9200	9200	1500	1378	1969	1712	3495	2231
DG-J	13600	13600	3790	1480	10340	2530	14738	3484
DG-K	26500	26500	2236	1523	5815	2557	9964	3622
DG-L	51700	51700	1475	1529	2309	2540	3341	3254

Option C
connections are hold

Latency	95 % - R		avg. (ms)		95 % - P		99 % - P	
All	-	-	2570	1852	6829	3429	14005	6032
DG-A	-	-	2366	2350	3797	3652	5330	5370
DG-C	1400	1400	1770	1848	3208	3280	4341	4498
DG-D	2400	2400	2041	2253	4308	4513	12771	12628
DG-F	4700	4700	3733	3245	6598	5038	11463	11113
DG-G	9200	9200	2252	2269	3897	3016	8009	3541
DG-J	13600	13600	3822	1585	10358	2773	18640	3508
DG-K	26500	26500	2516	1693	6251	2979	15079	4116
DG-L	51700	51700	1977	2368	3060	4016	3460	5827

Option D
connections are opened and closed on an "as needed" basis

Simulation Results

Other Observations

- Piggy backing of information more likely on FL than on RL
- Slight increase in data traffic (comparing C to D) – increased re-transmissions
- More signaling overhead (comparing D to C)
- Most application layer packets fit into a single TCP segment
- The TCP implementation as described in the paper causes quite some overhead

Latency	Avg. Offered load (kbps)		Avg. Throughput (kpbs)	
All (Option C)	96.46	18.52	77.13	17.40
All (Option D)	95.29	18.91	76.95	17.57

Conclusion

- Theoretical considerations have been acknowledged through simulation

- Enhance simulation tool-chain in iterative steps:
 - Study effects of single algorithms
 - Study available implementations

- At the end: come up with valuable recommendations for the aeronautical community!